



July 8, 2015

REPORT #E15-315

Influence Assessment: Establishing Data Exchange Standards Among Irrigation Manufacturers

Prepared by:
Cadmus Group
Bitsy Broughton
Jane Colby
Brett Peters

Northwest Energy Efficiency Alliance

PHONE

503-688-5400

FAX

503-688-5447

EMAIL

info@neea.org

Table of Contents

Executive Summary	1
1 Introduction.....	4
2 Methodology.....	5
2.1 Key Research Areas.....	5
2.2 Sample	6
2.3 In-depth Interviews.....	7
2.4 Scoring Protocol	8
3 Findings.....	12
3.1 Findings by Key Research Area	13
3.1.1 What are the agreed-upon standards [which resulted from PAIL’s efforts]?	13
3.1.2 How do standards work to create successful communication?.....	13
3.1.3 What have been PAIL’s accomplishments?.....	14
3.1.4 Have other entities made, planned, or foreseen similar developments?	16
3.1.5 How has NEEA impacted standards development and what would be the counterfactual?.....	17
3.2 Influence Scoring Results.....	19
4 Conclusions.....	20
Appendix A. Interview Guides	21
Appendix B. Data Sets and Equipment.....	33

Figures

Figure 1. Likelihood that Manufacturers and Stakeholders Would Have Worked Together without PAIL	17
--	----

Tables

Table 1. Research Overview	6
Table 2. Completed PAIL and Non-PAIL Interviews	8
Table 3. NEEA Direct Influence Questions (PAIL Members Only).....	9
Table 4. Key Counterfactual Questions, PAIL and Non-PAIL	10
Table 5. How effective has PAIL been in Establishing Data Exchange Standards?	12
Table 6. How likely is it that the Standard would have been established without PAIL and when?	13
Table 7. Attribution Scoring Summary.....	19

Executive Summary

In 2011, the Northwest Energy Efficiency Alliance (NEEA) launched an initiative aimed at improving the efficiency of center pivot irrigation. The solution was envisioned to be an integrated irrigation system with diverse components that could easily exchange information that would support data-driven irrigation decisions. The challenge was that the various system components were developed by disparate manufacturers. As a result, products from one company did not easily send information to or receive information from products made from a different company.

To address this barrier, NEEA invited a consortium of irrigation industry stakeholders, composed of equipment manufacturers, software companies, and irrigation consultants. The purpose of bringing these entities together was to develop and implement a universal set of data standards that could be used by all manufacturers, and that, when adopted, would allow for seamless data exchange between the various components of the irrigation system. Together with NEEA, the consortium initiated the Precision Ag Irrigation Leadership project (PAIL) within AgGateway.¹ PAIL achieved the primary objectives of its initial phase: writing data standards for collecting field information, such as soil moisture and weather conditions and forecasts, as well as for irrigation operations and reporting in December 2014. The work has since passed to the next phase, which entails submitting the formal standards and socializing those to the growers, manufacturers, and stakeholders in the industry. This next phase will also include the development of the next set of data standards, focusing on pumping systems, flow meters, energy, and drip irrigation. NEEA is partially funding this effort through December 2015.

NEEA engaged the Cadmus team, consisting of Cadmus and IRZ Technologies, in January 2015 to conduct an influence assessment. The primary objective of the evaluation was to assess NEEA's level of influence on developing and establishing the standards that would allow for data exchange to occur between the variously sourced components of an irrigation system.

Methodology

Utilizing in-depth interviews with 10 members of the PAIL Project and eight non-PAIL members of the irrigation industry, Cadmus assessed NEEA's influence on the development of standards in the following ways:

- Gathered information on PAIL participants' pre- and post-initiative plans, activities, and barriers to creating data exchange standards;
- Contrasted those outcomes to the plans, activities, and barriers perceived by non-PAIL industry representatives;
- Determined the counterfactual from PAIL participants' viewpoints, or what would have happened if NEEA had not initiated the process; and
- Identified the other impacts on market players, such as collaborations and mergers.

¹ "AgGateway is a non-profit consortium of businesses serving the agriculture industry with the mission to promote, enable and expand eBusiness in agriculture." More information is available online at: www.aggateway.org. Accessed April 15, 2015.

Key Research Areas

Cadmus, in conjunction with NEEA staff, developed five key research questions in which to focus our data collection. These included:

- What are the agreed-upon standards?
- How do standards work to create successful communication?
- What have been PAIL's accomplishments?
- Have other entities made, planned, or foreseen similar developments?
- How has NEEA impacted standards development and what would have occurred had NEEA not initiated the PAIL process?

Findings

PAIL members unanimously agreed that NEEA was very influential in establishing PAIL. Specifically, they spoke about NEEA's success in bringing competing manufacturers and the different stakeholders together around the same table to work on developing an integrated irrigation system. Many members cited three key factors: (1) NEEA's vision of a group to develop data exchange standards that would facilitate an integrated irrigation system; (2) NEEA's collaboration with AgGateway, a standards-writing organization; and (3) NEEA's funding and support of the PAIL facilitator, who the PAIL members said provided the administrative services and leadership necessary for the group to be successful.

Seven of 15 PAIL and non-PAIL respondents thought it was *not at all likely* or *not too likely* that a similar group of manufacturers and stakeholders would have worked together in a similar capacity if NEEA had not intervened to establish the PAIL consortium. Six respondents thought it was *somewhat likely*, and two respondents who thought it was *very likely* that a similar group would have worked together in a similar capacity. These two respondents said it would have occurred several years later; one estimated three to four years later and another said five to 10 years later.

When quantitatively scoring PAIL and non-PAIL members' responses to rate NEEA's overall influence on standards development, Cadmus separately asked PAIL members to rate NEEA's direct influence in establishing the standards, and then both PAIL and non-PAIL members to assess the likelihood of standards being developed had NEEA not initiated the PAIL process. The overall influence score was 84%, meaning in our estimation, the ultimate development of standards is 84% attributable to NEEA's efforts. PAIL members, rating on both NEEA's direct influence as well as the likelihood of standards being developed without NEEA, rated NEEA's overall influence at 85%. Non-PAIL members, who were only asked about the likelihood of standards occurring absent NEEA, provided scores calculating to 68% for NEEA's overall influence.

According to several of the participants we interviewed, growers are not yet demanding a standard because they have not had the opportunity to work with one. However, they said growers would adopt an integrated system once such a system is tested and if it increases the grower's return on investment.

Conclusions

Growers and technology advancements are creating a demand for better and easier collection of data and control of irrigation equipment. Prior to the work of PAIL, only sporadic efforts were undertaken to establish data exchange standards (and generally those standards only interacted with one or two brands). No industry-wide standard exists, effectively limiting a grower's ability to operate a fully integrated irrigation system using equipment from different manufacturers.

For data exchange standards to have a meaningful effect, manufacturers must agree to adopt them and build to the new protocols. As every PAIL and non-PAIL member pointed out, the largest challenge to developing any standard is gaining cooperation between competing irrigation industry stakeholders. NEEA successfully accelerated the time it may have taken for market demand or for manufacturers to cooperate on their own and develop an industry-wide standard.

1 Introduction

In 2011, the Northwest Energy Efficiency Alliance (NEEA) launched an initiative aimed at improving the efficiency of center pivot irrigation. The solution was envisioned to be an irrigation system with diverse components that could easily exchange information that would support data-driven irrigation decisions. The challenge was that the various system components were sourced from a variety of unrelated manufacturers. As a result, products from one company did not easily send information to or receive information from products made from a different company.

To address this barrier, NEEA invited a consortium of irrigation industry stakeholders, composed of equipment manufacturers, software companies, and irrigation consultants. The purpose of bringing these entities together was to develop and implement a universal set of data standards that could be used by all manufacturers, and that, when adopted, would allow for seamless data exchange between the various components of the irrigation system. Together with NEEA, the consortium decided to initiate the Precision Ag Irrigation Leadership project (PAIL) within AgGateway.² PAIL achieved the primary objectives of its initial phase in December 2014. The work has since passed to the next phase, which entails submitting the formal standards and socializing those to the growers, manufacturers, and stakeholder in the industry. This next phase will also develop the next set of data standards, focusing on pumping systems, flow meters, energy, and drip irrigation. NEEA is partially funding this effort through December 2015.

NEEA engaged Cadmus in January 2015 to conduct an influence assessment to assess NEEA's level of influence on developing and establishing the standards that would allow for data exchange to occur between the variously sourced components of an irrigation system. Those components could include sprinklers, emitters, sprayers, soil moisture monitors, soil mapping systems, in-field weather stations, and in-field eddy covariance systems.

Cadmus assessed NEEA's influence on the development of standards, in the following ways:

- Gathered information on PAIL participants' pre- and post-initiative plans, activities, and barriers to creating data exchange standards;
- Contrasted those outcomes to the plans, activities, and barriers perceived by non-PAIL industry representatives;
- Determined the counterfactual from PAIL participants' viewpoints, or what would have happened if NEEA had not initiated the process; and
- Identified the other impacts on market players, such as collaborations and mergers.

² "AgGateway is a non-profit consortium of businesses serving the agriculture industry with the mission to promote, enable and expand eBusiness in agriculture." More information is available online at: www.aggateway.org. Accessed April 15, 2015.

2 Methodology

Cadmus designed our project approach to provide an objective and insightful assessment of NEEA's influence in establishing a consortium of farm industry/irrigation stakeholders and facilitating the creation of standards that allow for exchange between irrigation system components. We reviewed the following documents:

- Irrigation Initiative Wrap-Up Report (Draft);
- Agriculture Irrigation Energy Efficiency Initiative Overview;
- Northwest Agricultural Irrigation Market Characterization and Baseline Study, and
- NEEA's Northwest Energy Efficiency Alliance Updates: *AgGateway Members and NEEA Collaborate on Energy-Efficient Agricultural Irrigation*

We also conducted in-depth interviews with both PAIL and non-PAIL members and scored NEEA's influence based on their responses.

2.1 Key Research Areas

Following our review of NEEA project documents, Cadmus, in conjunction with NEEA staff, developed five key research areas to guide our in-depth conversations with PAIL and non-PAIL members. Table 1 provides an overview of the key research questions, areas of investigation, and data sources that contributed to our analysis.

Table 1. Research Overview

Research Question	Areas of Investigation	PAIL Draft Wrap-Up Report	Market Characterization and Baseline Study	NEEA Product Manager	PAIL Lead Facilitator	PAIL Manufacturers	Non-PAIL Manufacturers	Utility Representatives
What are the agreed-upon standards?	Specific standards associated with specific components; How standards were identified; Technical specifications	✓		✓	✓	✓		
How do standards work to create successful communication?	Compare end product description to needs; Demonstrate project results; Demonstrate education, outreach, and marketing results	✓		✓	✓	✓	✓	✓
What have been PAIL’s accomplishments?	Goals versus achievements; Challenges; Successes; What is left for PAIL to do	✓		✓	✓	✓		
Have other entities made, planned, or foreseen similar developments?	Perceived market need by others; Similar product development initiatives by non-PAIL manufacturers; Level of progress toward similar development; Whether other entities would have conducted the PAIL work		✓	✓	✓	✓	✓	✓
How has NEEA impacted standards development and what would be the counterfactual?	Absent PAIL, what standards/when would they have been established and what are the likely differences in results; Change in technology development status pre-2012 to post-2014; Factors important to change; Projected saturation of equipment		✓	✓	✓	✓	✓	✓

2.2 Sample

NEEA provided Cadmus with a list of 28 representatives of manufacturers and universities throughout the Northwest who participated in the PAIL project. Additionally, NEEA provided us with contacts at two utilities who work closely with growers in the Northwest, but who were not

participants in the PAIL consortium. IRZ Consulting³ provided Cadmus with a list of 17 irrigation equipment manufacturer and university personnel, also located primarily in the Northwest, who work with growers but did not participate in the PAIL consortium.

Cadmus segmented both PAIL and non-PAIL contacts by the type of equipment they manufactured or businesses/institution they represented. These equipment types included, sprinklers, sprayers, or emitters; soil moisture management equipment; in-field weather stations; and controls software. Participants who were not manufacturers were drawn from utilities, universities and large agribusiness organizations.

Within these categories, PAIL participants were further sorted by their level of participation in PAIL, from most active to least active. Cadmus randomly dialed PAIL and non-PAIL contacts from each equipment segment until we fulfilled the interview goals or exhausted the sample.

2.3 In-depth Interviews

Cadmus was able to speak to representatives from each of the manufacturing, institutional, and utility sectors. Thirteen of the 18 PAIL and non-PAIL participants interviewed have careers in the agriculture irrigation industry, ranging from 10 to 46 years in length. They have a deep understanding of the issues, concerns, and opportunities faced by both manufacturers and growers.

Four non-PAIL members were very familiar with NEEA and PAIL, having either worked with NEEA since its inception, as funders of NEEA's work, as an industry liaison to NEEA, or through participating in other NEEA irrigation studies. Two of the non-PAIL members attended the initial meetings in which the PAIL initiative was developed, and they continue to receive limited updates on PAIL. The remaining four interviewees were slightly familiar or had not heard of NEEA or PAIL prior to our conversation. Table 2 shows the sample size and completed interviews by business type.

³ IRZ combines water resource engineering with state-of-the-art technologically advanced irrigation, resource management (water, power, and human) and conservation services to their clients, and is well acquainted with members of the irrigation industry,

Table 2. Completed PAIL and Non-PAIL Interviews

Role	PAIL			Non-PAIL		
	Sample Population	Interview Goal	Interviews Completed	Sample Population	Interview Goal	Interviews Completed
PAIL Lead Facilitator	1	1	1	N/A	N/A	N/A
Manufacturers of sprinklers, sprayers, or emitters; large agribusiness	6	1-5	1	8	1-5	3
Manufacturers of soil moisture management equipment	7	1-5	1	4	1-5	1
Representatives of in-field weather stations	3	1-5	1	1	1-5	*
Representatives of farm system software company	7	1-3	3	4	1-3	1
Utility or university representative with irrigation experience; Other	1 University	N/A	1	2 Utility; 1 University	1-2	2 Utility; 1 University
NEEA Product Manager	1	1	1	N/A	N/A	N/A
Total	28	Up to 10	10	19	Up to 10	8

* Many of the companies represented manufacture equipment in more than one category. The category (in-field weather stations) was represented in our interview with the manufacturer of soil moisture and management equipment.

2.4 Scoring Protocol

Cadmus designed a scoring protocol to quantitatively assess NEEA’s *overall influence* in the development and implementation of a universal set of data standards through responses to interview questions of PAIL manufacturers, non-PAIL manufacturers, and other stakeholders. The questions assessed two components of the *overall influence*: (1) NEEA’s *direct influence* in establishing the consortium and ultimately achieving the standards; and (2) what would be the *counterfactual*, (i.e. would standards have been established without NEEA and when?). When scored, each component has a percentage of *overall influence* ranging from 0% to 100% for each interviewee. These two components are potentially subject to different and opposing biases as interviewees tend to “agree” with statements made in interviews more often than “disagree.” The *direct influence* questions asked for level of agreement that NEEA and PAIL were influential, while the *counterfactual* questions asked for level of agreement that others would have implemented a similar effort, absent NEEA’s involvement. As a result, the *direct influence* component may indicate higher *overall influence* than the *counterfactual* component. We

averaged each component’s score across all interviewees, and then averaged the two component scores together to compute an *overall influence* result ranging from 0% to 100%. While those involved with PAIL answered both the *direct influence* and *counterfactual* assessments, non-PAIL manufacturers were only asked a subset of the *counterfactual* questions that generally assess the likelihood of manufacturers joining forces to develop standards similar to those resulting from PAIL.

We assessed *direct influence* through two questions:

- How influential was NEEA in establishing PAIL?
- How effective was PAIL in establishing standards?

We assessed the *counterfactual* by asking both PAIL and non-PAIL members how likely it was that similar standards would have been developed absent PAIL, and when they would have been developed. PAIL members were asked specifically about individual standards, while non-PAIL members were asked generally about an overall effort. We asked the PAIL facilitator, NEEA product manager, and PAIL academic member to answer the attribution questions for each equipment standard, along with a question to rate the importance of that standard in the overall irrigation system. For these three respondents, we scored the *counterfactual* by weighting the scores for each component by the importance of that component to the irrigation system. We first computed the importance-weighted *counterfactual* score for the specific standard questions, then averaged those results with the general *counterfactual* questions. The interview guide contains other questions that are used for context, probing, and confirming responses to the attribution questions.

Table 3 and Table 4 list the key *direct influence* and *counterfactual* component questions and the scores associated with different responses.

Table 3. NEEA Direct Influence Questions (PAIL Members Only)

Key Questions	Scoring				
1. How influential was NEEA in establishing PAIL?	Not at all influential	Not too influential	Neutral	Somewhat influential	Very Influential
	0%	25%	50%	75%	100%
2. How effective was PAIL in establishing the standards?	Not at all effective	Not too effective	Neutral	Somewhat effective	Very effective
	0%	25%	50%	75%	100%

Table 4. Key Counterfactual Questions, PAIL and Non-PAIL

Key Questions*	Scoring				
1. [PAIL + non-PAIL] How likely is it that others [organizations or individuals] would have established something similar [to PAIL]?	Very likely	Somewhat likely	Neutral	Not too likely	Not at all likely
	0%	25%	50%	75%	100%
2. [PAIL] How likely is it that [specific equipment] standard ** would have been established without PAIL?	Very likely	Somewhat likely	Neutral	Not too likely	Not at all likely
	0%	25%	50%	75%	100%
3. [PAIL] Without PAIL, would the [specific equipment] standard be different [than PAIL's result]?	Very similar	Somewhat similar	Neutral	Somewhat different	Very different, or yes, or don't know
	0%	25%	50%	75%	100%
4. [PAIL] Without PAIL, when would [specific equipment] standard have been established?	Same or within 1 year	In 1 to 2 years	In 3 to 4 years	In 4 to 5 years	A long time or more than 5 years
	0%	25%	50%	75%	100%
5. [PAIL] How important is that particular [specific equipment] standard to overall communications standards?	Not at all important	Not too important	Neutral	Somewhat important	Very important
	0%	25%	50%	75%	100%

6. [PAIL + non-PAIL] How similar to PAIL and how successful are other equipment management collaboration efforts?	Very similar/ successful	Somewhat similar/ successful	Neutral	Not too similar/ successful	Not at all similar/ successful or N/A
	0%	25%	50%	75%	100%
7. [PAIL + non-PAIL] When did this work occur?	Completed during 2011- 2014	Started prior to or during 2011-2013	Started in 2014-2015	Planning to start	Don't know or N/A
	0%	25%	50%	75%	100%

* Questions are presented for clarity in this report and actual wording may differ slightly from the interview guides. Actual question wording is provided in the interview guides in the Appendix A.

** A list of data sets and equipment is provided in Appendix B.

3 Findings

Cadmus conducted in-depth interviews with PAIL and non-PAIL participants to assess their awareness of PAIL’s work, to collect data about PAIL’s progress in developing data exchange standards, and to assess NEEA’s influence. Those findings are presented below, starting with an overview of NEEA’s influence on the formation of PAIL and the standards, and then organized by key research areas. Section 3.2 provides a more detailed analysis of the influence scoring results.

PAIL members unanimously agreed that NEEA was very influential in establishing PAIL. Specifically, they spoke about NEEA’s success in bringing competing manufacturers and the various stakeholders together around the same table to work on developing an integrated irrigation system. Many members cited three key factors: (1) NEEA’s vision of a group to develop data exchange standards that would facilitate the creation and use of an integrated irrigation system; (2) NEEA’s collaboration with AgGateway, a standards-writing organization; and (3) NEEA’s funding and support of the PAIL facilitator, who the PAIL members said provided the administrative services and leadership necessary for the group to be successful.

PAIL members only, were then asked about PAIL’s effectiveness in establishing the data exchange standards. Seven of 10 members said that PAIL had been *very effective* in establishing the standards and three said *somewhat effective* (Table 5).

Table 5. How effective has PAIL been in Establishing Data Exchange Standards?

How effective has PAIL been in establishing data exchange standards among irrigation equipment from different manufacturers? (n=10)	Very Effective	Somewhat Effective
	7	3

Each PAIL member was also asked about the likelihood the standard for their individual equipment would have been established without PAIL. A majority of the respondents thought it was unlikely standards would have been established with two saying *not to likely* and five saying *not at all likely*. Only two respondents thought it was *somewhat likely* standards would have been established. One agribusiness member declined to answer, as his company does not manufacture equipment.

In addition, none of the nine respondents to this question thought the standards would have been established in the same timeframe. Seven respondents said it would have been in more than five years, if at all. Three of those seven said the standards would never have been established. However, two respondents thought standards would have been established sooner than five years. Table 6 shows the detailed responses to these questions.

Table 6. How likely is it that the Standard would have been established without PAIL and when?

	Somewhat Likely	Not too Likely	Not at all Likely
How likely is it that this standard would have been established without PAIL? (n=9)	2	2	5
When do you think the standard would have been established? (n=9)	Three to Four years	Four to Five Years	More than Five Years
	1	1	7

3.1 Findings by Key Research Area

This section is organized by key research area and includes select questions from each area. Findings from the numerous questions asked in each research area are synthesized and reported below.

3.1.1 What are the agreed-upon standards [which resulted from PAIL’s efforts]?

PAIL members identified protocols for sprinklers, sprayers and emitters, soil moisture monitoring or management equipment, soil mapping systems, in-field weather systems, and farm systems software. After evaluation, soil mapping was less significant than the other standards.

In addition, one PAIL member said that two components, pump monitoring and energy monitoring (smart meters), are not part of the current protocols. He said PAIL could not get strong commitments from pump manufacturers and, although PAIL members could write the standard without industry actors participating, PAIL wanted their engagement so they would take the standards seriously. He said the same was true of energy monitoring (smart meters) manufacturers. These issues are being addressed in Phase 2.

3.1.2 How do standards work to create successful communication?

The standards developed by PAIL will allow growers using irrigation components manufactured by different companies, to communicate with his/her irrigation equipment as one integrated system. For example, one manufacturer described how standards will tie together data from soil moisture probes, rainfall catch buckets, weather stations and pivot controls, which will provide the grower with a complete picture of the field conditions, from which to make his/her irrigation decisions. Another respondent who manufactures pivot monitor and control devices, said standards will allow his product to communicate with any pivot regardless of manufacturer.

3.1.2.1 How important are data exchange standards to your business or to the growers?

During our interviews with PAIL and non-PAIL participants, one pivot manufacturer provided a particularly informative perspective on the importance of communication standards, to growers today. He described today's growers as “kids who want to run their farm from their phone.” He went on to say, “Programmable logic will manage the system and allow this.” He explained that center pivots are especially well-suited to automation and make up 30% of the sprinkler-irrigated land in the Northwest⁴. He pointed out that center pivot manufacturers have been automating their equipment for 10 years, but now this will incorporate the other components, such as weather data, to form an integrated “master system.”

Other manufacturers told Cadmus that they are all working to develop standards, but none are interchangeable with other manufacturer's equipment. They said the development of a standard for data exchange will “level the [competitive] playing field,” allowing growers to select equipment from different sources rather than being tied to one manufacturer.

A third respondent said he felt data exchange standards are extremely important to growers because there is a lot of water wasted and there will not be enough water to support the growing population. A NEEA representative stated that widespread application of integrated irrigation systems would more efficiently use this scarce resource.

Utility and university respondents provided a different perspective on how important data exchange standards will be to growers. One utility representative said that growers are not yet demanding a standard because, although the vision of a fully integrated irrigation system has been around for some time, growers have not had the opportunity to work with one. He said he thought they would want an integrated system once they had the opportunity to use one. Another respondent said:

“Standards will only be important to growers if they increase their ROI [return on investment]; otherwise they will not adopt [irrigations systems that use them] Growers are probably not aware nor care about this right now but standardization will be important to manufacturers to develop tools that will work together.”

3.1.2.2 What are the challenges to developing these standards?

PAIL and non-PAIL members responded unanimously: the biggest challenge to developing irrigation equipment standards is getting competitive manufacturers to sit down together, commit the time, and identify and agree upon standards.

3.1.3 What have been PAIL's accomplishments?

PAIL has completed Phase 1 of the project, writing data exchange standards for collecting field information. The PAIL team had an initial submissions discussion with AgGateway Standards and Guidelines committee. The committee recommended PAIL make some technical, detailed

⁴ NEEA published an estimate that center pivots are used on 50% of NW irrigated land in the “Northwest Agricultural Irrigation Market Characterization and Baseline Study Report” sourced from the “USDA Farm and Ranch Irrigation Systems Report (2008).

changes in the XML code and asked them to provide more explanatory comments. PAIL is completing those and will re-submit to AgGateway early in May. Once approved by AgGateway, the standards will be published for comment and submitted to ASABE.

NEEA's *Agricultural Irrigation Initiative: Data Exchange Standards* draft report dated January 28, 2015, states that Phase Two of the PAIL project will focus on socializing with industry actors the data standards developed to date, and developing and testing the next set of data standards. Those standards will include pumps, pump systems, infrastructure, drip-irrigation, sub-surface, fixed and other overhead watering practices.

3.1.3.1 What is the benefit of having a group of market actors come together to create standards?

NEEA initiated the PAIL consortium to develop data exchange standards to facilitate the creation of integrated irrigation systems. These standards will allow components from various manufacturers to be incorporated into any given system, rather than just specific proprietary systems, thereby expanding opportunities for the manufacturers, and making it easier for growers to collect and use data.

All PAIL and non-PAIL participants were asked what they think is the benefit of having a group of competitive manufacturers come together to create standards. For PAIL participants, the benefits varied. Many felt that the benefit was to have an integrated system of components to enable decision-making, lessen the time growers spend converting data from various equipment types, and to decrease costs (both water usage and labor).

PAIL members also saw benefits for manufacturers who, while working together on the standards, gain insight into other manufacturers' viewpoints. This type of learning influences changes within their own companies. Finally, development of standards will allow further automation, which is necessary for innovation and advancement of the irrigation equipment industry.

Non-PAIL participants responded similarly. They pointed out that, with fully integrated data exchange standards, growers will have more confidence in which equipment types they choose to purchase because they are not locked into one manufacturer's system or even specific components attached to the system. Growers will also spend less time deciding which components are compatible and do not have to recreate their database each time they upgrade.

Like PAIL members, two non-PAIL members felt that there is a benefit to having manufacturer's come together, listen each other, and ultimately reach a shared understanding. As one non-PAIL member said, "Manufacturers will build to a standard so the customers know the equipment will work with other manufacturers' equipment. The end user benefits from any standard."

3.1.3.2 How would the development of these standards help improve irrigation efficiency in the Northwest?

When asked how standards would improve irrigation efficiency, some respondents pointed out that, currently, any savings discussed are conceptual savings that still need to be proven in field tests. They said, intuitively, however, standards should enable methods to collect data, allowing growers to look at local data rather than data from more distant weather stations, and this should improve savings because the information will be more accurate.

NEEA representatives added that standards should hasten the development and deployment of integrated irrigation systems, which should generate savings. Additionally, an integrated system will enable data collection which ultimately will facilitate better evaluation of water and energy use.

Other respondents questioned whether standards would help save water, but they said standards will allow for more automation of the work humans are doing, which will improve efficiency and reduce labor costs.

One non-PAIL participant said:

“Farmers are relatively efficient but to take the next step [of efficiency] this kind of interaction needs to take place.”

However, many respondents described a variety of benefits. The following responses are representative of this viewpoint:

- Growers will be more willing to adopt systems that use the standards making efficient practices more understandable, and simplify the way data is “moved around the web.”
- Growers will no longer have to make an educated guess as to how much water to apply; rather, they will have more accurate, precise data because all of his/her equipment will be able to talk to each other.
- Growers will no longer have to consult with a third party to integrate all of the data from different in-field irrigation equipment. Instead, growers will be able to purchase any software because it will be compatible with any equipment out there.

One respondent said he does not believe standards alone will improve irrigation efficiency in the Northwest unless they have the effect of speeding up the adoption of the irrigation technologies.

3.1.4 Have other entities made, planned, or foreseen similar developments?

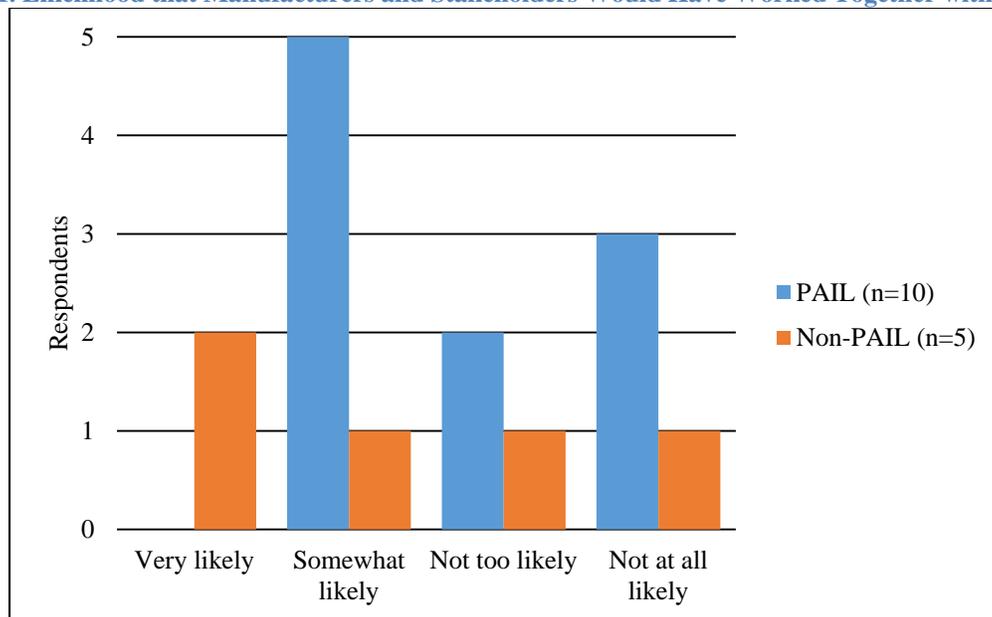
Of the PAIL and non-PAIL members, 10 of the 18 people interviewed said they were not aware of any other cases of representatives from different irrigation equipment manufacturers working together to accomplish a common goal in the past three years. However, eight said that they were aware of such work. These eight respondents named organizations such as the Irrigation Association (IA) in Washington, D.C., whose members work together on an on-going basis to influence the Farm Bill, and the American Society of Agricultural and Biological Engineers (ASABE) who develop standards for the agriculture industry. They also described manufacturers

partnering on individual specific equipment, such as drip irrigation, sprinkler controls, and software interface for sensors. Respondents thought the partnerships on drip irrigation and sprinkler controls occurred between 2011 and 2013, the same timeframe as the PAIL project. One respondent said the software collaboration began in 2015.

3.1.4.1 How likely is it that manufacturers and other stakeholders would have worked together in a similar capacity if NEEA had not intervened to establish the PAIL consortium?

PAIL and non-PAIL participants, were asked how likely is it that manufacturers and other stakeholders would have worked together in a similar capacity if NEEA had not intervened to establish the PAIL consortium. Seven of 15 respondents thought it was *not at all likely* or *not too likely* that a similar group would have worked together. Six respondents thought it was *somewhat likely*, and two respondents who thought it was *very likely* that a similar group would have worked together in a similar capacity. These two said it would have occurred several years later; one estimated three to four years later and another said five to 10 years later. Figure 1 shows the how 15 PAIL and non-PAIL members responded. Three respondents did not answer the question.

Figure 1. Likelihood that Manufacturers and Stakeholders Would Have Worked Together without PAIL



3.1.5 How has NEEA impacted standards development and what would be the counterfactual?

In this research area, Cadmus explored changes occurring in the irrigation industry during the time PAIL was convened and working with manufacturers, and examined whether manufacturers, utilities, and university organizations had changed as a result of this work.

3.1.5.1 Changes in the Irrigation Industry

Cadmus asked all interviewees what changes had occurred in the irrigation industry since 2011 when the PAIL initiative was first envisioned. One respondent's answer summed up answers of many others. He said, "A lot of little things [have occurred] more than one big thing."

Respondents cited changes such as:

- Improvements in pivots;
- Increased adoption of technology (more so than the introduction of new technology);
- Trends toward better automation of controls through improved telemetry and GPS; and
- The use of drones taking infrared photos showing where crops are stressed and need additional water.

The driving forces behind these changes, respondents said, are:

- Increasing labor costs and the decreasing cost of technology, particularly for controls;
- Dramatic advancements in cell phone technology, allowing growers to control more from their phones;
- Needed water conservation; and
- Competition and growers' demand for more data.

3.1.5.2 How has the work PAIL has done influenced these changes?

PAIL members answered this question more easily than the non-PAIL members who had less direct information of the work that has taken place. Cadmus found that knowledge of PAIL and its work was not widespread outside of the PAIL team. However, one PAIL and one non-PAIL manufacturer responding to this question said that they have not yet seen any influence of the standards because the standards work has not yet come to fruition and the technology changes are still being embraced by growers and manufacturers.

Six respondents thought PAIL had influenced technology changes in a number of ways, such as bringing manufacturers to the table at the right time to develop the language that will connect irrigation components to the "cloud" and meeting with growers to ensure the precision harvesting processes look and feel the same as before the standards. One manufacturer said his company has taken action and increased sprinkler control points 20-fold.

3.1.5.3 Has your organization/company changed as a result of your participation in PAIL?

Respondents spoke about changes they see in the future, once the standards are completed, socialized, and adopted by manufacturers and growers. Integration is now a more realistic outcome. One manufacturer said his company is thinking more broadly about joining with other companies, seeing the possibility of "widgets connecting to other widgets." Another company told Cadmus, "Data science is a priority to our company. We have made some strategic hires." In addition, one manufacturer said that, since participating in PAIL, he has learned more about the technical needs of other companies and he is making a better product because of it. He concluded, "I didn't even know how well they used our schedules."

3.2 Influence Scoring Results

As described above, Cadmus applied a methodology to quantify NEEA’s overall influence by scoring responses to interview questions in two categories: *direct influence*, asked of PAIL members about NEEA’s influence and effectiveness in establishing PAIL, and *counterfactual*, asked of both PAIL and non-PAIL members to assess the likelihood of standards being developed absent NEEA’s work. Accounting for all interview responses, with equal weighting for each participant, we calculated NEEA’s overall influence score to be 84%. The *direct influence* score was 96% and the *counterfactual* score was 71%, which means that based on the methodology used, NEEA’s influence and PAIL’s effectiveness was 90% responsible for standards development, and the likelihood that another entity would *not* have achieved a similar result was 71%.

All PAIL participants answered the *direct influence* questions asking about NEEA’s influence in establishing PAIL as well as PAIL’s effectiveness in establishing the standards. Individual scores for these questions ranged from 88% to 100%, with an overall average of 96%. We also asked PAIL participants *counterfactual* questions about likelihood of individual standards being created without PAIL, its similarity to the PAIL standards and timing, and in general, the likelihood of another similar effort of collaboration among manufacturers, and its similarity to the PAIL collaboration and timing. The *counterfactual* score for PAIL members ranged from 46% to 95% and averaged 74%.

For non-PAIL members, the *counterfactual* score ranged from 17% to 99% and averaged 68%. The overall counterfactual score for PAIL and non-PAIL members combined was 71%. The PAIL lead, NEEA facilitator, and PAIL academic member (PAIL non-manufacturers) tended to have attribution scores that were higher than either the PAIL manufacturers or the non-PAIL manufacturers. The PAIL manufacturers scored NEEA’s *overall influence* to be higher than non-PAIL manufacturers.

Table 7 **Error! Reference source not found.** summarizes the scores for different groups of respondents and the overall scores.

Table 7. Attribution Scoring Summary

Role	PAIL			Non-PAIL			Overall
	Manufacturers	Non-Manufacturers	All	Manufacturers	Non-Manufacturers	All	All
Direct Influence	96%	96%	96%	N/A	N/A	N/A	96%
Counterfactual	67%	91%	74%	56%	75%	68%	71%
Overall Influence	82%	94%	85%	56%	75%	68%	84%

4 Conclusions

Growers and technology advancements are creating a demand for better and easier collection of data and control of irrigation equipment. Prior to the work of PAIL, only sporadic efforts were undertaken to establish data exchange standards (and generally, those standards only interacted with one or two brands). No industry-wide standard exists, effectively limiting a grower's ability to operate a fully integrated irrigation system using equipment from different manufacturers.

For data exchange standards to have a meaningful effect, manufacturers must agree to adopt them and build to the new protocols. As every PAIL and non-PAIL member pointed out, the largest challenge to developing any standard is gaining cooperation between competing irrigation industry stakeholders. NEEA successfully accelerated the time it may have taken for market demand or for manufacturers to cooperate on their own and develop an industry-wide standard.

Appendix A. Interview Guides

NEEA Irrigation Data Exchange Standards PAIL Manufacturers Interview

Cadmus will interview both PAIL members and non-PAIL industry experts to gather information needed to assess NEEA’s influence in establishing a consortium of farm industry/irrigation stakeholders and facilitating the creation of standards that allow for communications among irrigation system components. The table below identifies key research objectives and interview groups that will contribute to our analysis. Each research question is listed in front of the survey questions throughout the guide.

Research Question	Question Numbers	Areas of Investigation
What are the agreed-upon standards?	15	<ul style="list-style-type: none"> • How standards were identified
How do standards work to create successful communication?	16-20	<ul style="list-style-type: none"> • Specific standards associated with specific components (what is needed to create a successful communication platform) • Compare end product description to needs
What have been PAIL’s accomplishments?	6-14, 21-31	<ul style="list-style-type: none"> • Goals versus achievements • Influence of NEEA on establishing PAIL • Benefits of PAIL • Demonstrate project results • Challenges • Successes
Have other entities made, planned, or foreseen similar developments?	32-35	<ul style="list-style-type: none"> • Perceived market need by others • Similar product development initiatives by non-PAIL manufacturers • Level of progress towards similar development • Whether other entities would have conducted the PAIL work
How has NEEA impacted standards development and what would be the counterfactual?	Error! Reference source not found. -40	<ul style="list-style-type: none"> • Absent PAIL, what standards would have been established (and when) and what are the likely differences in results • Change in technology development status pre-2012 to post-2014 • Factors important to change

Cadmus will make every effort to preschedule all interviews. However, if some interviewees cannot be reached in advance, the following introduction will be used.

[Definition if needed: An integrated irrigation decision support solution (IIDS) will make it easy for growers to lower their irrigation electrical energy use, reduce their operating costs and improve profitability.]

[If more information is needed continue reading:

The IIDS product solution consists of a common software architectural platform with:

1. Pre-planting soil mapping survey capability
2. A common application programming interface (API) that:
 - a. receives soil moisture data

- b. receives current and near-future weather conditions
- 3. A database to store and retrieve the above data
- 4. A data analysis engine to calculate the optimum amount of irrigation needed to maximize profit given the conditions
- 5. A simulation program that allows users to enter different use case scenarios
- 6. Ability to send reports and recommended actions for optimum irrigation
- 7. Provide update information and control direct to a “smart phone” or other portable devices.]

Introduction

[PAIL Manufacturers] Hello, my name is [NAME] and I am calling from Cadmus on behalf of the Northwest Energy Efficiency Alliance, or NEEA. NEEA is conducting a study to understand its level of influence on developing and establishing the standards that would allow for data exchange to occur between the variously sourced components of an irrigation system. As a member of PAIL, your perspective will be valuable to our research.

We are conducting a survey which will take about 30 minutes. Would you be willing to participate? (If not now, may we schedule a time that is convenient for you?) Thank you.

1. First, can you tell me about your role at [company name]?
2. How long have you worked in the irrigation field?
3. What type of equipment does your company specialize in? [Mark all that apply]
 1. Sprinklers, sprayers, or emitters
 2. Soil moisture monitoring or management equipment
 3. Soil mapping systems
 4. In-field weather stations
 5. Farm system software
 6. In-field eddy covariance systems
 97. Other (specify)
4. Can you please describe your role working with the Precision Ag Irrigation Leadership consortium, or PAIL?
 1. How long have you been a PAIL participant
 2. Why did you get involved?
 3. Are you aware of other groups working on establishing similar standards? [If Yes, please describe what is similar and different]
5. Why was PAIL formed?

What have been PAIL’s accomplishments?

Thank you. Now I’d like to ask you about PAIL’s goals and accomplishments.

6. What are PAIL's goals?
7. Have the goals changed since PAIL began?
 1. In what ways?
8. Do you think PAIL has met these goals? Why do you say that? (Probe for evidence the goals have been met)

NEEA's influence in establishing the PAIL consortium

9. How influential was NEEA in establishing PAIL? (Do not read "Neutral" option. Use neutral only when interviewee specifically indicates they are really neutral or "somewhere in the middle". Select don't know when they specifically say "I don't know".)
 1. Very influential
 2. Somewhat influential
 3. Not too influential
 4. Not at all influential
 98. Don't know
 99. Refused
 100. Neutral
10. Can you tell me why you say that?
11. [If not covered above] Specifically, what has NEEA done to facilitate the establishment of this group?
12. What is the benefit to having a group of market actors come together to create standards which could allow interfacing between components of a system built by competitive manufacturers?
13. How likely is it that manufacturers and other stakeholders would have worked together in a similar capacity if NEEA had not intervened to establish the PAIL consortium? Would you say...? (Do not read "Neutral" option. Use neutral only when interviewee specifically indicates they are really neutral or "somewhere in the middle". Select don't know when they specifically say "I don't know".)
 1. Very likely
 2. Somewhat likely
 3. Not too likely
 4. Not at all likely
 98. Don't know

- 99. Refused
- 100. Neutral

14. Do you see a need for NEEA to be involved going forward? (If so, in what way?)

What are the standards?

Thank you. Now, I'd like to ask you about the data exchange standards that PAIL is working to establish.

15. How did you identify what standards need to be developed?
- 1. [If not covered above] Who was involved in this process and how?

How do standards work to create successful communication?

16. Regarding [equipment type], which components need to interface with what other components to enable successful data exchange?
17. [Ask for each equipment type named in Q43, for non-equipment contacts ask question more generically] When PAIL started, what standards did you think were needed to allow [equipment type from Q43] to communicate with other equipment through the integrated platform envisioned by NEEA?
18. How would the development of these standards help to improve irrigation efficiency in the Northwest?
19. Did the idea of what was needed change or evolve along the way? In what way(s)?
20. Were the results at the end of Phase One different than what you thought they would be? If so, how? [If needed read: Phase One was the work performed by PAIL toward developing data standards. This work was transitioned to the American Society of Agricultural and Biological Engineers (ASABE)].

PAIL's influence in establishing standards

21. How effective has PAIL been in establishing data exchange standards among irrigation equipment from different manufacturers? Would you say...? (Do not read "Neutral" option. Use neutral only when interviewee specifically indicates they are really neutral or "somewhere in the middle". Select don't know when they specifically say "I don't know".)
- 1. Very effective
 - 2. Somewhat effective
 - 3. Not too effective

- 4. Not at all effective
 - 98. Don't know
 - 99. Refused
 - 100. Neutral
22. Specifically, what conceptual data communication standards [insert response to Q43] have been established as a result of the work PAIL has done?
- 1. [RECORD]
 - 2. None **[SKIP to Q29]**
23. **[Ask Q23 - Q28 for each standard identified in Q22]** How likely is it that this standard would have been established without PAIL? Would you say...? (Do not read "Neutral" option. Use neutral only when interviewee specifically indicates they are really neutral or "somewhere in the middle". Select don't know when they specifically say "I don't know".)
- 1. Very likely
 - 2. Somewhat likely
 - 3. Not too likely
 - 4. Not at all likely
 - 98. Don't know
 - 99. Refused
 - 100. Neutral
24. How important is this particular standard to the overall communication between components? (Do not read "Neutral" option. Use neutral only when interviewee specifically indicates they are really neutral or "somewhere in the middle". Select don't know when they specifically say "I don't know".)
- 1. Very important
 - 2. Somewhat important
 - 3. Not too important
 - 4. Not at all important
 - 98. Don't know
 - 99. Refused
 - 100. Neutral
25. Without PAIL, would the standard have been developed in the same timeframe?
- 1. Yes
 - 2. No
 - 98. Don't know
 - 99. Refused

26. **[If Q25 = No]** When do you think this standard would have been established?

1. Within the same year
2. In one to two years
3. In three to four years
4. In four to five years
5. In more than five years
98. Don't know
99. Refused

27. Without PAIL, do you think the standard would be any different?

1. Yes
2. No
98. Don't know
99. Refused

28. **[If Q27 = Yes]** How would it be different? ([Probe for details here.](#))

Challenges

29. What challenges has PAIL faced in developing the standards?

30. How were these challenges overcome?

Successes

31. Outside of the standards development we have already discussed, what else has PAIL accomplished?

Have other entities made, planned, or foreseen similar developments?

Thank you. Now I'd like to ask you about similar product development initiatives by non-PAIL manufacturers.

32. In the past three years, are you aware of any other cases of representatives from different irrigation equipment manufacturers working together to accomplish a common goal?
What entities were involved?

33. **[If Q32 = Yes]** Can you please describe this work? How similar or dissimilar is it to the work PAIL is doing?

34. **[If Q32 = Yes]** When did this work occur?

35. **[If Q32 = Yes]** Was this work successful? Why or why not?

How has NEEA impacted standards development and what would be the counterfactual?

Change in technology development status pre-2012 to post-2014

36. What technology changes have occurred in the irrigation industry since 2011?

Factors important to change

37. What factors were most influential in achieving these changes? [For example, commodity prices, enabling technology, consumer demand, or an outside influence such as PAIL. May need to ask about each change separately.]

38. How has the work PAIL has done influenced these changes?

Changes in PAIL participant's company as a result of their participation

39. Has your company changed as a result of your participation in PAIL? In what ways?

40. In your opinion, what is the most effective way “get the word out” and to socialize these standards among the players in the irrigation industry?

Closing

In closing, is there anything else you would like to add? Is there anything we failed to ask you that you think is important to evaluating NEEA's level of influence on developing and establishing PAIL or the data exchange standards?

Thank you for your time and the information you shared with us.

NEEA Irrigation Data Exchange Standards Non-PAIL and Utility Interview

Cadmus will interview both PAIL members and non-PAIL industry experts to gather information needed to assess NEEA’s influence in establishing a consortium of farm industry/irrigation stakeholders and facilitating the creation of standards that allow for communications among irrigation system components. The table below identifies key research objectives and interview groups that will contribute to our analysis. Each research question is listed in front of the survey questions throughout the guide.

Research Question	Question Numbers	Areas of Investigation
How do standards work to create successful communication?	50-54	<ul style="list-style-type: none"> • How important are data exchange standards • Demonstrate benefits of standards • Challenges to establishing standards
Have other entities made, planned, or foreseen similar developments?	55-58	<ul style="list-style-type: none"> • Perceived market need by others • Similar product development initiatives by non-PAIL manufacturers • Level of progress towards similar development • Whether other entities would have conducted the PAIL work
How has NEEA impacted standards development and what would be the counterfactual?	59-66	<ul style="list-style-type: none"> • Absent PAIL, what standards would have been established (and when) and what are the likely differences in results • Change in technology development status pre-2012 to post-2014 • Factors important to change

Cadmus will make every effort to preschedule all interviews. However, if some interviewees cannot be reached in advance, the following introduction will be used.

[Definition if needed: An integrated irrigation decision support solution (IIDS) will make it easy for growers to lower their irrigation electrical energy use, reduce their operating costs and improve profitability.]

[If more information is needed continue reading:

The IIDS product solution consists of a common software architectural platform with:

1. Pre-planting soil mapping survey capability
2. A common application programming interface (API) that:
 - a. receives soil moisture data
 - b. receives current and near-future weather conditions
3. A database to store and retrieve the above data
4. A data analysis engine to calculate the optimum amount of irrigation needed to maximize profit given the conditions
5. A simulation program that allows users to enter different use case scenarios
6. Ability to send reports and recommended actions for optimum irrigation
7. Provide update information and control direct to a “smart phone” or other portable devices.]

Introduction

Hello, my name is [NAME] and I am calling from Cadmus on behalf of the Northwest Energy Efficiency Alliance, or NEEA. NEEA is conducting a study to understand its level of influence on developing and establishing the standards that would allow for data exchange to occur between the variously sourced components of an irrigation system. As a member of [the irrigation equipment manufacturers' community] [a utility that serves a large irrigation community], your perspective will be valuable to our research.

We are conducting a survey which will take about 10-20 minutes. Would you be willing to participate? (If not now, may we schedule a time that is convenient for you?) Thank you.

41. First, can you tell me about your role at [company name]?
42. How long have you worked in the irrigation field?
43. **[Ask non-PAIL manufacturers]** What type of equipment does your company specialize in? **[Mark all that apply]**
 1. Sprinklers, sprayers, or emitters
 2. Soil moisture monitoring or management equipment
 3. Soil mapping systems
 4. In-field weather stations
 5. Farm system software
 6. In-field eddy covariance systems
 98. Other (specify)
44. Before today were you familiar with the Northwest Energy Efficiency Alliance, or NEEA?
 1. **[If YES]** How did you learn about it?
 2. No
45. Have you heard about the Precision Ag Irrigation Leadership consortium, or PAIL?
 1. **[If YES]** How did you learn about it?
 2. No **[SKIP to Q49]**
46. Before today were you aware of NEEA's involvement in bringing together members of the irrigation equipment community to form PAIL?
 1. **[If YES]** How did you learn about it?
 2. No
47. Before today were you aware of PAIL's initiative to create standards which could allow interfacing between components of a system built by competitive manufacturers?
 1. **[If YES]** How did you learn about it?
 2. No **[SKIP to Q49]**

48. Do you receive updates about the work being done by NEEA or PAIL on this initiative?
5. **[If YES]** How did you receive that information?
 6. No

49. What is the benefit to having a group of market actors like PAIL, come together to create standards which could allow interfacing between components of a system built by competitive manufacturers?

How do standards work to create successful communication?

Thank you, now I'd like to ask you about the importance of data exchange standards in **[your business/for your growers.]**

50. In your opinion, how important are data exchange standard for irrigation equipment to **[non-PAIL manufacturer "your business" or Utility "your growers"]**?
51. **[Ask: non-PAIL manufacturers]** Regarding **[equipment type named in Q43]**, which components need to interface with what other components to enable successful data exchange?
52. Do you think there is a need in the irrigation market in the Northwest for this type of integrated system? Why or why not?
53. How would the development of these standards help to improve irrigation efficiency in the Northwest?
54. What are the challenges to developing these standards?

Have other entities made, planned, or foreseen similar developments?

Thank you. Now I'd like to ask you about similar product development initiatives by non-PAIL manufacturers.

55. In the past three years, are you aware of any other cases of representatives from different irrigation equipment manufacturers working together to accomplish a common goal? **[IF NO: SKIP to Q64]**
56. **[If Q55 = Yes]** Can you please describe this work?
57. **[If Q55 = Yes]** When did this work occur?
58. **[If Q55 = Yes]** Was this work successful? Why or why not?

59. How likely is it that manufacturers and other stakeholders would have worked together in a similar capacity if NEEA had not intervened to establish the PAIL consortium? Would you say...?

1. Very likely
2. Somewhat likely
3. Not too likely
4. Not at all likely **[SKIP to 64]**

101. Don't know

102. Refused

60. What entities would have been involved and in what role?

61. When do you think this work would have occurred?

62. How would it be similar to what PAIL is doing?

63. How would it be different from what PAIL is doing?

How has NEEA impacted standards development and what would be the counterfactual?

Change in technology development status pre-2012 to post-2014

64. What technology changes have occurred in the irrigation industry since 2011?

Factors important to change

65. What factors were most influential in achieving these changes? **[For example, commodity prices, enabling technology, consumer demand, or an outside influence such as PAIL. May need to ask about each change separately.]**

66. **[SKIP if they have not heard of PAIL]** How has the work PAIL has done influenced these changes?

Closing

In closing, is there anything else you would like to add? **[If they've heard of PAIL, ask]** Is there anything we failed to ask you that you think is important to evaluating NEEA's level of influence on developing and establishing PAIL or the data exchange standards?

Thank you for your time and the information you shared with us.

Appendix B. Data Sets and Equipment

PAIL Data Set	Data Field Group	Data Field Name	Applicable Equipment/ Technologies							Regional Weather Station, such as CIMIS, Agrimet, Mesonet
			Field Weather Stations	Soil Moisture Sensors	Pumping Systems	Flow Meters	Pivots	Pivot Controller	Person or FMIS	
Set Up and Configuration	User	User ID							X	
		User Password							X	
	Date	Time Stamp Current							X	
		Time Stamp Past							X	
	Location	Country							X	
		State/Province							X	
		County							X	
		Site							X	
		Field						X		
All Hardware Units		Device Type	Y	Y	Y	Y	Y	Y		
		Brand	Y	Y	Y	Y	Y	Y		
		Device ID	Y	Y	Y	Y	Y	Y		
		Node ID								
		Parent Node								
		Battery								
	H/W Location	Location	Y		Y		Y			
	Soil Sensors									

PAIL Data Set	Data Field Group	Data Field Name	Applicable Equipment/ Technologies							Regional Weather Station, such as CIMIS, Agrimet, Mesonet
			Field Weather Stations	Soil Moisture Sensors	Pumping Systems	Flow Meters	Pivots	Pivot Controller	Person or FIMS	
	Pivot Equipment	End Gun					Y			
		Total Length					Y			
		Spans					Y			
		Center Pivot Location					Y			
		Corner System					Y			
		Pivot Turn					Y			
		Pumping System			Y		Y			
		Design Flow Rate								
		Design PSI								
		Zone Configuration								
		Sprinkler Package								
Primary End Point										
	Controller Config of Pivot	Controller Type					Y			
		Turn					Y			
		End Gun Control					Y			
		Swing Arm					Y			
		VRI Capability					Y			
		VFD					Y			
		Wedge					Y			
		Safety Light					Y			
		Auxiliary Control					Y			
		Communication					Y			
Operational					Y					
	Pumping Systems	VFD (Constant flow or PSI)								
		Wedge Angle and Qty								
		Safety Light								
		Aux control input and output								

Inbound	Data Field Group	Data Field Name	Applicable Equipment/ Technologies							Regional Weather Station, such as CIMIS, Agrimet, Mesonet	
			Field Weather Stations	Soil Moisture Sensors	Pumping Systems	Flow Meters	Pivots	Pivot Controller	Person or FMIS		
	Soil Moisture			X							
	Soil Map								X		
	Local Weather		X						X		
Remote Data	Regional Weather Forecast	Offsite Source								X	
		Weather Network Data Set Type								X	
		Meteorological Codes Reference									X
		Meteorological Value Reference Table Type									X
		Weather Network Record Type									X
Planning Data	Crop Plans								X		
	Field Conditions								X		
Work Order	When	Start/End date-time of slice					X	X	X		
	What	Coverage					X	X	X		
	Where	Applied Area					X	X	X		
	How Much	Total Water put on irrigated area					X	X	X		
	Products	Products System is Applying					X	X	X		
Work Record (aka As Applied)	When	Start/End date-time of slice					X		X		
	What	Coverage					X		X		
	Where	Applied Area					X		X		
	How Much	Total Water put on irrigated area					X		X		
	Products	Products System is Applying					X		X		
		Stipulations	Alarms Triggered					X		X	
		Other Deltas from Work Order					X		X		
	Water Pumped	To be completed in PAIL 2			X		X				
Energy Used	To be completed in PAIL 2			X		X					